Fluctuational Analysis of Nighttime Ground-Level Ozone Concentrations due to Variations in Hourly Relative Humidity

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Abstract. Ground-level ozone (O_3) is formed by photochemical reactions between precursors and sunlight, which are controlled by climatic conditions such as relative humidity and temperature. As a result, the purpose of this research was to examine into the influence of relative humidity and temperature in the fluctuation and transformation of O_3. The Department of Environment (DoE) contributed hourly monitoring data for O_3, relative humidity, and temperature in Shah Alam in 2010, which then was extracted for the nighttime O_3 data. Descriptive statistics, box and whisker plots, time series, and diurnal plots were used to examine the observations. Descriptive statistics, box and whisker plots, time series, and diurnal plots were used to examine the observations. During the night, the diurnal plot revealed an inverse link between O_3 concentration and relative humidity. During the night, however, temperature is positively associated with O_3 concentration. The diurnal trend of O_3 concentration revealed that it was greater during the day than at night. As a result of the pollutant deposition process being reduced, decreased air humidity permitted higher ground level ozone concentrations in the atmosphere.

Index Terms: Air pollution, secondary air pollutant, precursors, photochemical reactions, temperature, Malaysia

I. INTRODUCTION

Air pollution is a persistent and widespread environmental issue that has health and economic consequences. Any chemical, physical, or biological material emitted from an outdoor or indoor environment that affects the natural characteristics of the atmosphere is referred to as air pollution [1]. Primary and secondary pollutants are the two types of pollutants found in the air. Primary pollutants include sulphur dioxide emitted directly from industry, ash from volcanic eruptions, and carbon monoxide gas generated by cars [2]. Meanwhile, pollutants that are not emitted directly from point sources are known as secondary pollutants [3]. Ground level ozone is one of the important examples of secondary pollutants [4]. Ozone is colorless gas with chemical formula O_3, is the minor constituents of the atmosphere [5]. High concentration of ozone decreased health quality that effect from human activities and was altered the concentration of ozone. During daytime, increased number of vehicles on the roads has contributed to higher ozone precursors thus generating more ozone concentration [6]. In contrast, the number of vehicles is lesser during nighttime, thus limiting the ozone precursor concentrations. Other climatic parameters that impact ground level ozone concentration include relative humidity, temperature, wind speed, and direction [7]. Wet ozone deposition on water droplets is often linked with low ozone levels during rainy weather with high relative humidity [8]. A case study on the air quality in the urban areas of Brazilian Midwest has reported that increasing relative humidity caused the reduction of ozone [9]. Generally, ozone concentrations are low during nighttime due to the absence of photochemical reactions. However, higher reductions in nighttime ozone concentrations was also associated with increased in the nighttime NO concentrations [10]. Furthermore, ozone concentrations surged in the afternoons when temperatures were high and relative humidity was low, indicating that ozone formation is substantially influenced by sunlight and relative humidity [8]. Even though the amount of solar radiation and presence of O_3 precursors influenced the fluctuation of O_3, meteorological parameters such as wind and relative humidity also influenced the O_3 concentration [10]. Due to the lack of information and understanding, the diurnal variations for ground level ozone, temperature and relative humidity during nighttime are barely investigated in Malaysia. So, this study investigated the influence of relative humidity and temperature on the ground level ozone concentrations sinking reactions during nighttime

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II. MATERIALS AND METHODS

2.1 Study Area

This study was conducted in Shah Alam, Selangor with coordinates 3°4′20″N 101°31′00″E. According to World Population Review [11], Shah Alam having about 481,654 populations. The rapid transformation of Shah Alam into a wide urban area has caused many environmental challenges, particularly air pollution. For instance, higher ozone levels could be associated with emitted precursors from the nearby indutrial areas and the increasing use of vehicles in the urban area. As a result, this study analyzed the effect of temperature and relative humidity on ground level ozone throughout the night in Shah Alam.

2.2 Data Acquisition

Hourly ground level ozone concentration was acquired from Department of Environment, Malaysia. The ozone concentration data that acquired from DOE were between 1st January until 31st December 2010 which recorded using the UV Absorption Ozone Analyzer Model 400A by DOE [12]. Due to the high level of O3 concentration released or emitted in the atmosphere at that time, these data were subjected to quality control on a routine basis. To carry out the analysis, all data was organised by location, year, month, and day. According to Enviro Technology Services, for measuring low ranges of ozone in ambient air, system based on Beer-Lambert law using UV Absorption Ozone Analyzer Model 400A. Ozone in the sample cell absorbs a 254 nm UV light signal that passes through it, with a range of 0-100 ppb to 0-10 ppm. DOE also employed the Portable Humidity Temperature Meter Model to measure temperature and the Met One 083D to monitor relative humidity.

2.3 Data Analysis

In this study data of hourly ground-level ozone, temperature and relative humidity in Shah Alam, Selangor was chosen for analyzed. Hourly data of ground-level ozone, temperature and relative humidity from 7.00 p.m. to 7.00 a.m. which the period of nighttime in Malaysia was recorded. The total duration for this study carried out was 12 hours during nighttime. Univariate data analysis is crucial for this kind of data to investigate unknown and unexpected features in the dataset descriptively. Therefore, discriptive statistical analysis that involved box and whisker plot which visualised the standard deviation, variance, the minimum and maximum of the data has been used to anlyze the continuous data of hourly relative humidity, temperature during nighttime influenced ozone concentration. Time series analysis was also used to analyze the data of hourly ground-level ozone, temperature and relative humidity in Shah Alam, Selangor. This analysis has been used due to the previous study by Awang et al. [13] that detected the highest ground level ozone concentration in actual time. The time series was seperately ploted using O_3 concentration (ppb), relative humidity (%) and temperature data as y-axis and time hours during nighttime from 7 p.m. to 7 a.m. as x-axis. Lastly, The hourly fluctuation of ground level ozone concentration was examined visually using diurnal plot. In this study, diurnal plot was used graphically and the variation of ground-level ozone concentration against meteorological factors such as temperature and relative humidity were explored [13]. Hourly trends, maximum and lowest concentration times, and diurnal amplitude have been calculated. For diurnal variations analysis, data of O_3 concentration (ppb), relative humidity (percent), and temperature (^oC) were plotted on the y-axis, while 24 time hours from 7 p.m. to 7 a.m. were plotted on the x-axis. Due to the influence of solar radiations, diurnal analysis revealed that the oscillations of O_3 concentration throughout the night and day are clearly different.

III. RESULT AND DISCUSSION

3.1 Descriptive statistics of ground level ozone, temperature and relative humidity

Box and whisker plot were developed to graphically illustrate the variations of ground level ozone concentration. The box and whisker plot of ozone concentration, relative humidity, and temperature during nighttime in 2010 were depicted in Figure 1. Based on Figure 1, the highest record of O_3 concentration was during February and the lowest record of O_3 concentration during nighttime was in June. The variations variations in nighttime O_3 is highly depend on its nighttime removal chemistry as well as meteorological parameters that promote deposition and transport prosess of the pollutants. The exhibited result was clearly influence by meteorological factors such a relative humidity that act as wet deposition agents. Malaysia located in tropical regions which received high intensity of rainfall especially the monsoonal rains that contribute to high relative humidity which in between 80% to 90 % all year around. Malaysia was classified into four seasonal monsoon, different monsoon indicated different values of relative humidity and temperature due migration of trade winds occur, movement of air toward the equator. Malaysia experience northeast monsoon during November to march while southwest monsoon during June to September while for transitional period, first inter-monsoon during April to May and second inter-monsoon period during October to November. During northeast monsoon and Malaysia considered as wet season and contribute lower pollutants concentration due to high relative humidity and lower temperature. February indicates highest amount of O_3 in Figure 1 and contribute to lowest amount of relative humidity which below 40 % and temperature was slightly increase than November.

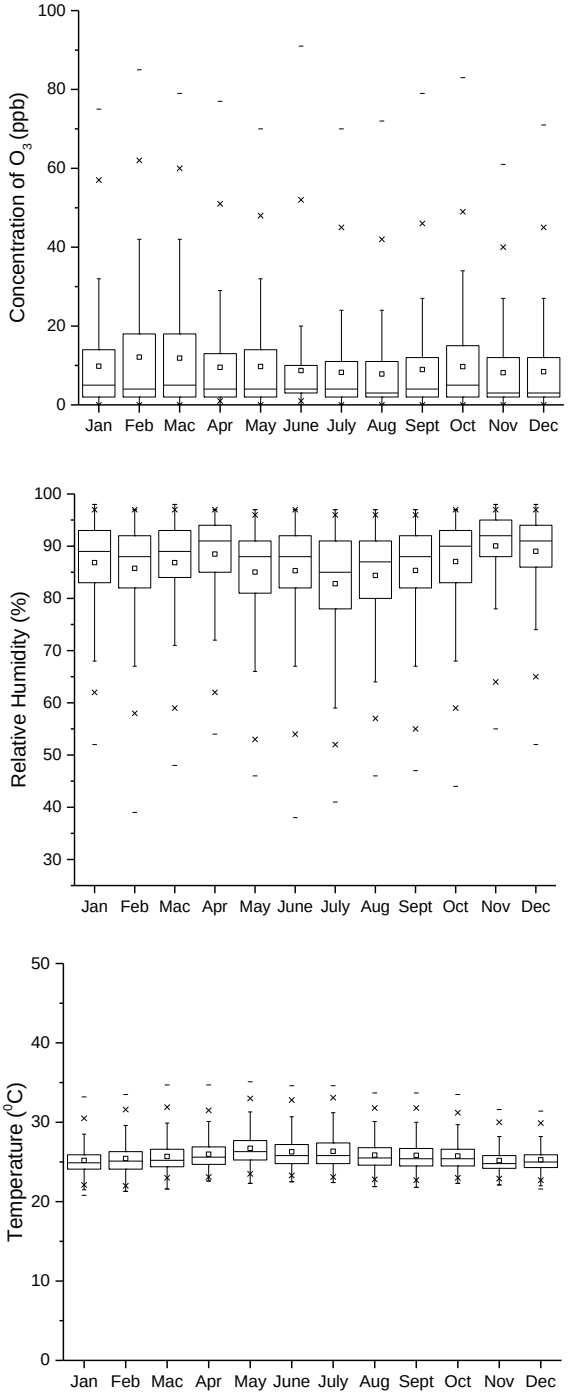

Figure 1 Box and whisker plot of average nighttime O_3 concentration in 2010

3.2 Time-series Analysis of Concentration of O3, Relative Humidity and Temperature

The O_3 concentration, relative humidity and temperature in Shah Alam during nighttime in 2010 were analyzed using time and series plots as showed in Figure 2. Result suggested that increased of relative humidity influenced the decreased the O_3 concentration and there is directly proportional between O_3 concentrations and temperature. Decreased amount O_3 concentration during late nighttime due to increase relative humidity and precursor for O_3 formation has been used up. According to Toh et al. [14] high temperature, low wind speed, low relative humidity and intense solar radiation can raise O_3 concentration.

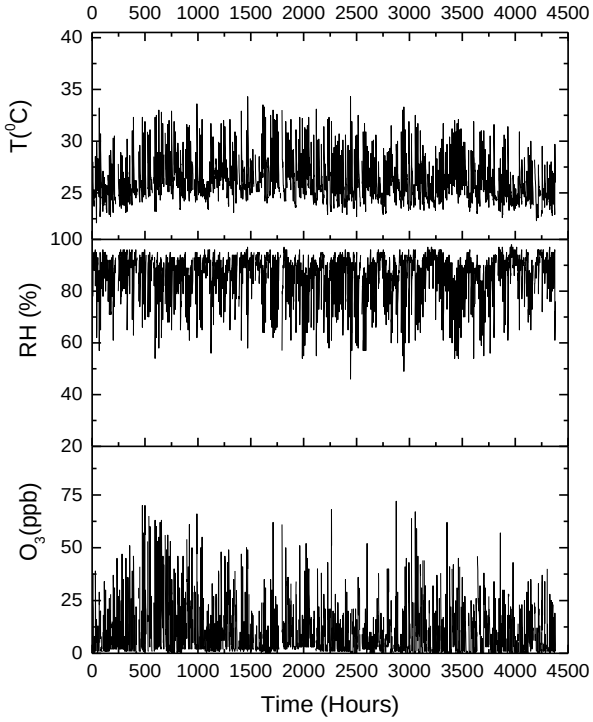

Figure 2 Time series plot of nighttime O_3 concentration, relative humidity and temperature in 2010

3.3 Diurnal variations of Concentration of O3, Relative Humidity & Temperature

The average diurnal plots were produced to analyze the data for 24 hours monitoring during in 2010. The graph was shown in Figure 3 to visualize the trend of O_3 concentration, relative humidity and temperature. The diurnal magnitude for O_3 concentration during daytime was higher than nighttime due to sources of emission that promote higher photochemical reactions and suitable meteorological factors. The concentration started increase during peak hour from 12.00 p.m. to 2 p.m. at maximum solar radiation intensity combined with increase in O_3 precursors concentrations that were various economic activities such as motor vehicles and industrial. The O_3 concentration was slightly decrease during 6 p.m. because of O_3 precursors was efficiently used up for photochemical reactions and there is no production due to absence of sunlight. Based on this research, there was high concentration of O_3 during daytime rather than nighttime due to absence of photochemical reactions and during nighttime high relative humidity promote further O_3 removal from the atmosphere [15]. Futher reduction during nighttime also governed by increasing relative humidity during nighttime that acts as deposition agents which binds O_3 gases and deposited to ground surface. Nevertheless, low

nighttime O3 concentration during nighttime is mainly attributed by ceasing in photochemical reactions due to the absence of sunlight, while high relative humidity further enhancing the removal prosess.

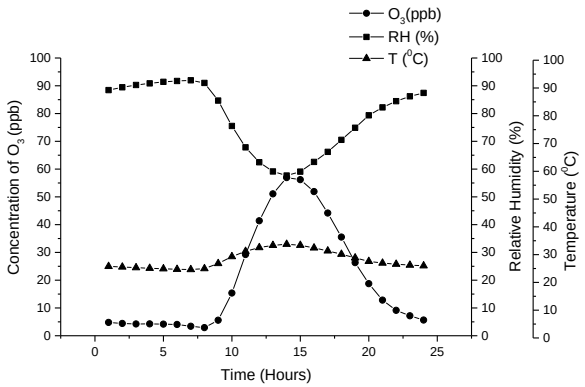

Figure 3 Diurnal plot of O_3 concentration, relative Humidity and temperature in 2010

IV. CONCLUSION

This study investigate the relationwhip between O_3 concentrations, relative humidity and temperature during nighttime. Result strongly suggested that nighhtime O_3 concentrations were inversely related with relative humidity but directly proposional to daily temperature variations. However, the result also suggested nighttime ozone removal is not highly depended on relative humidity but most of the time depended on nighttime removal chemistry as there were exact trend were detected between O_3 and relative humidity variatians. It is because, low nighttime O3 concentration during nighttime is mainly attributed by ceasing in photochemical reactions due to the absence of sunlight, while high relative humidity further enhancing the removal prosess.

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